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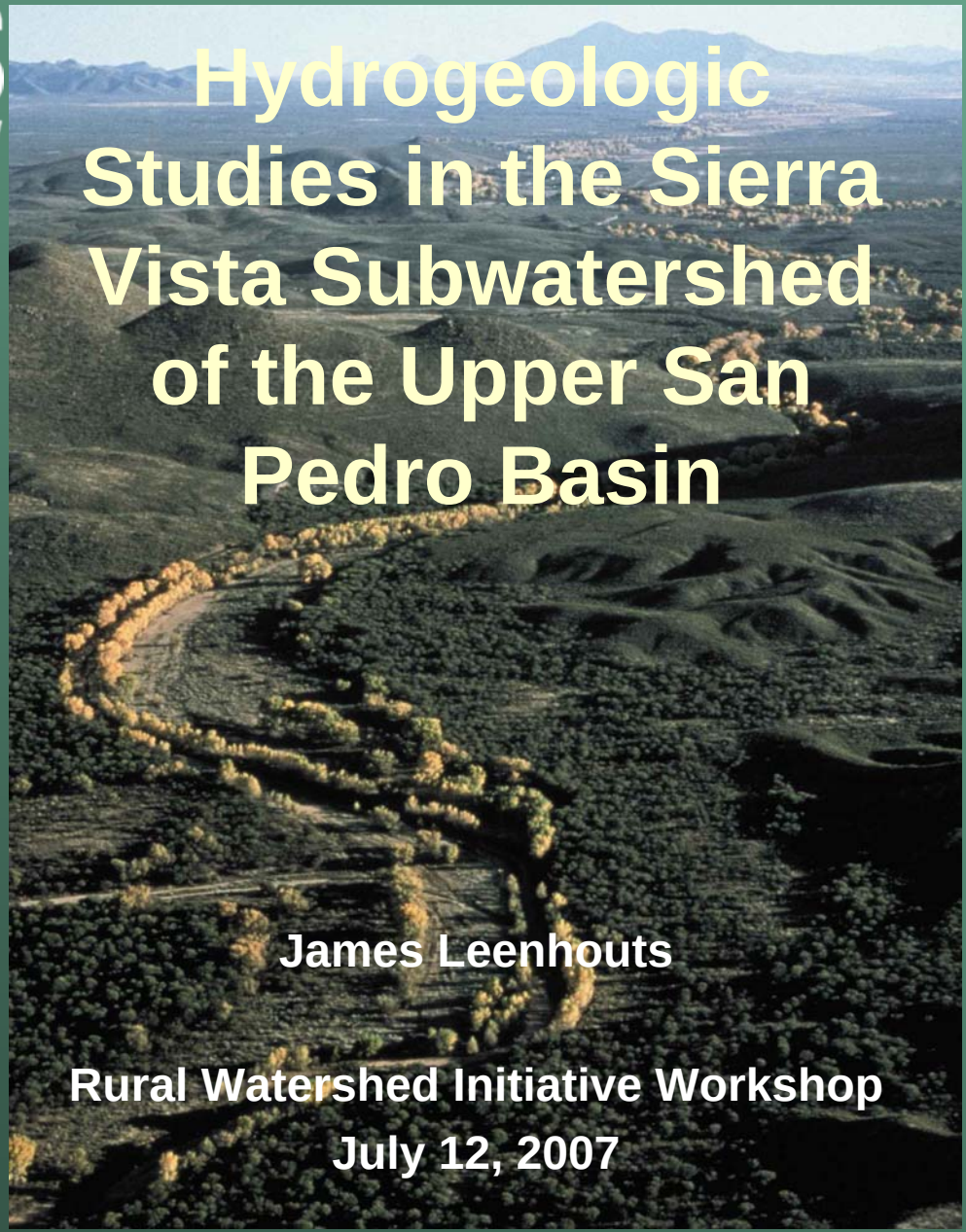

Hydrogeologic Studies in the Sierra Vista Subwatershed of the Upper San Pedro Basin

James Leenhouts

Rural Watershed Initiative Workshop

July 12, 2007

U.S. Department of the Interior
U.S. Geological Survey

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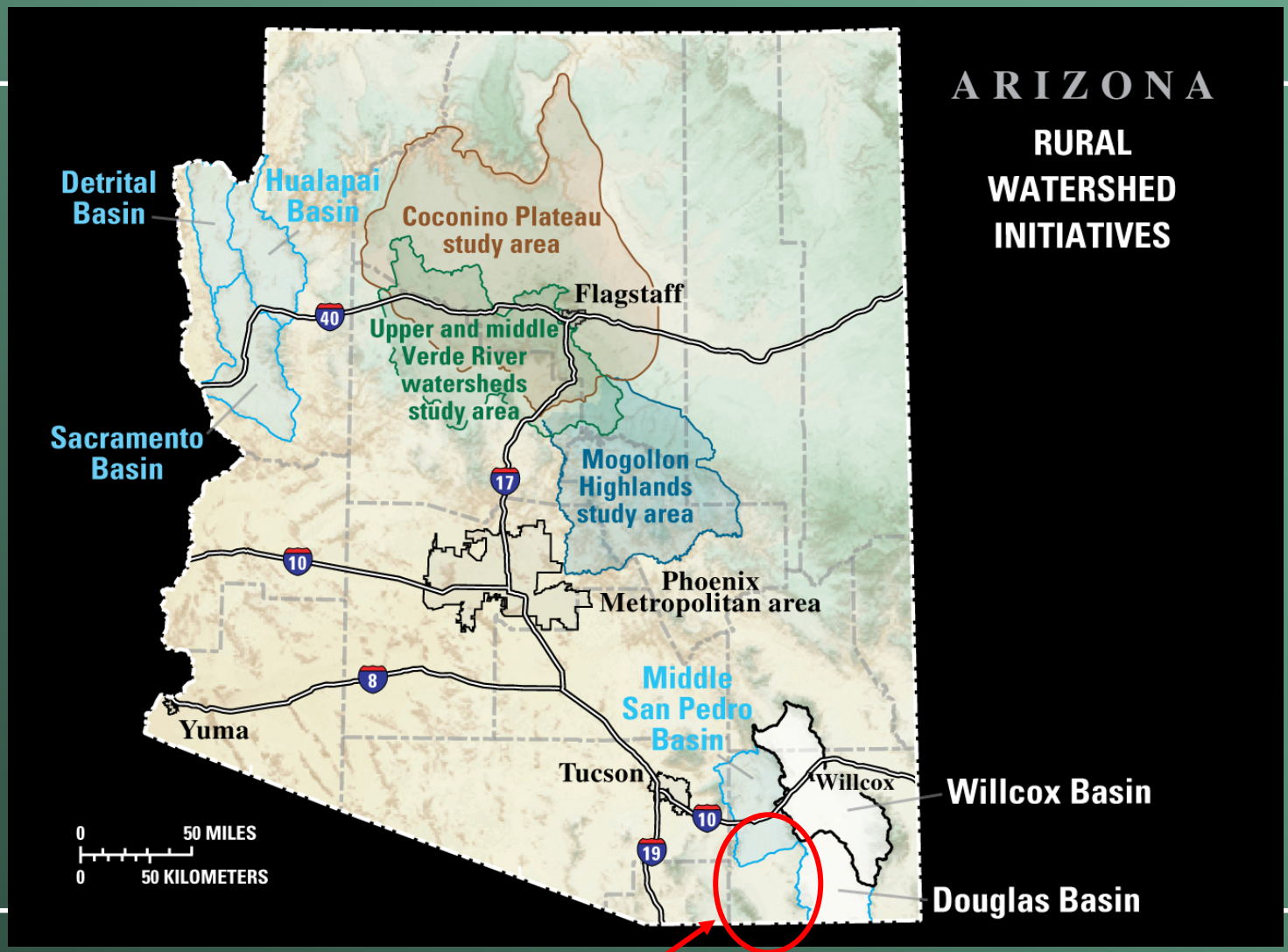

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Upper San Pedro

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The Upper San Pedro Basin - Key Study Area Characteristics

- San Pedro River flows north from near Cananea, Mexico to Gila River
- Alluvial basin aquifer
- Perennial streamflow
- Protected riparian ecosystem
- Ground-water dependent population
- Growing population

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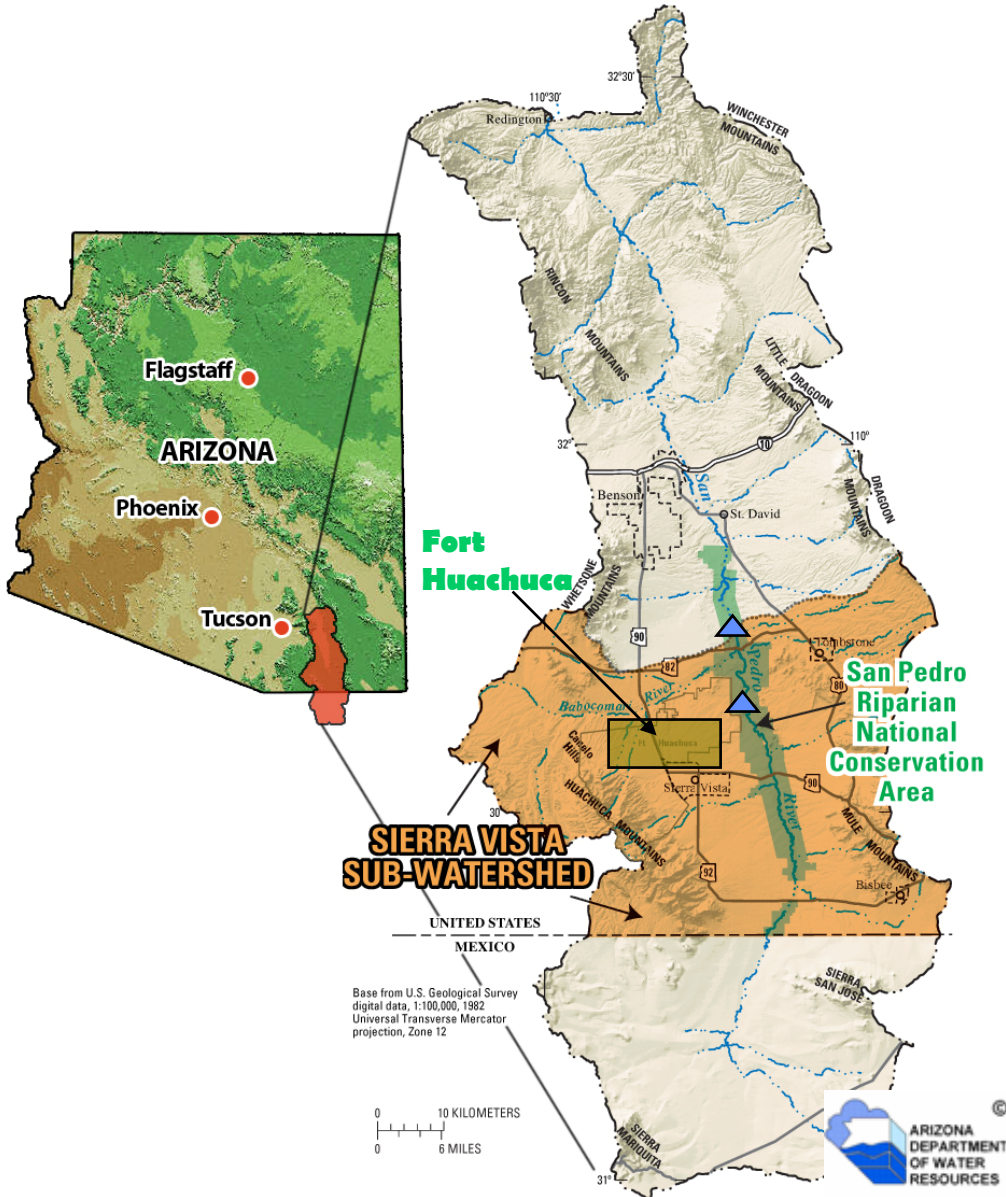
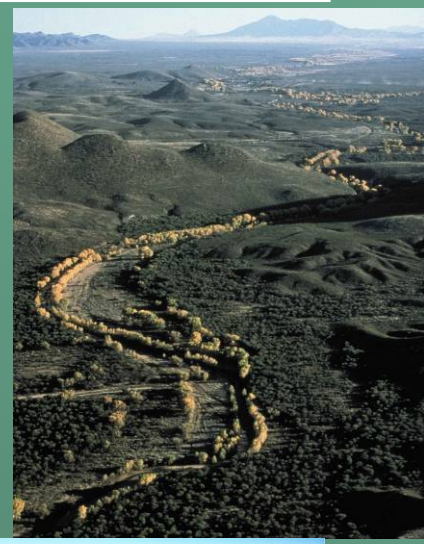
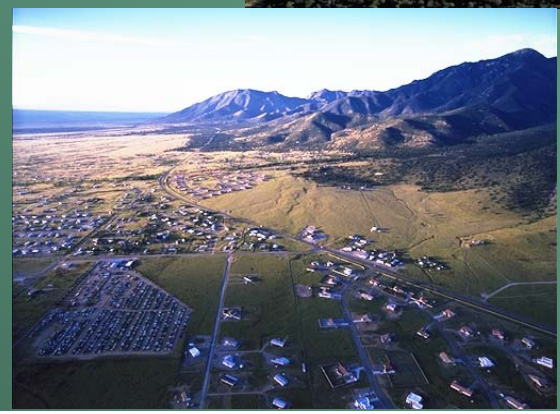


The Issue: Competing Assets

- The San Pedro's riparian system (SPRNCA)
  - Federally protected in 1988
  - One of shrinking number of free-flowing perennial rivers in the Southwest



- The human community
  - National asset: Fort Huachuca
  - Growing population
  - Great climate, beautiful environs



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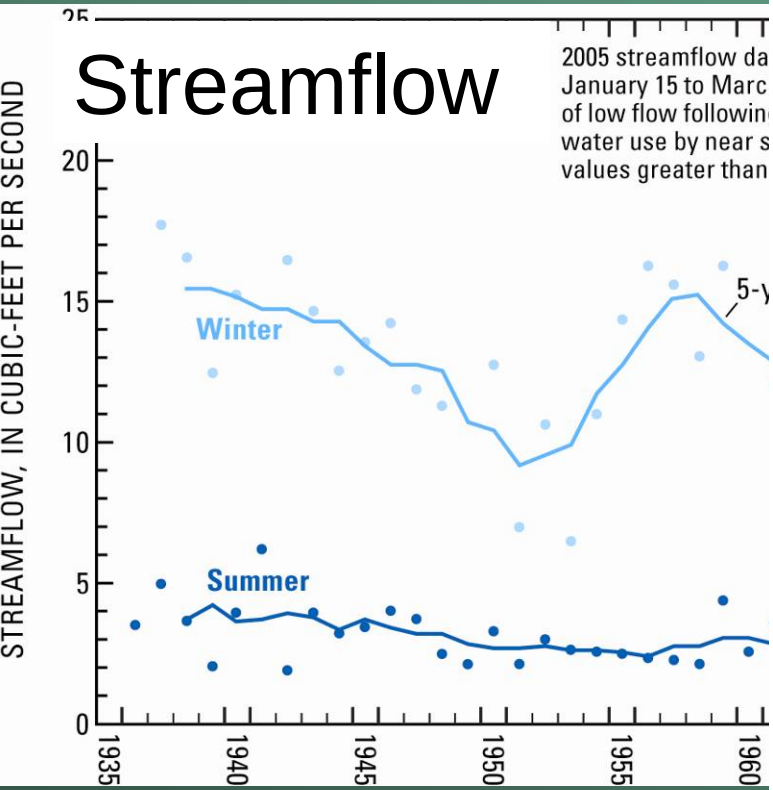
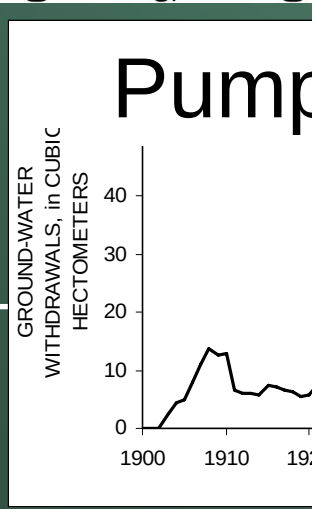
Streamflow at Charleston





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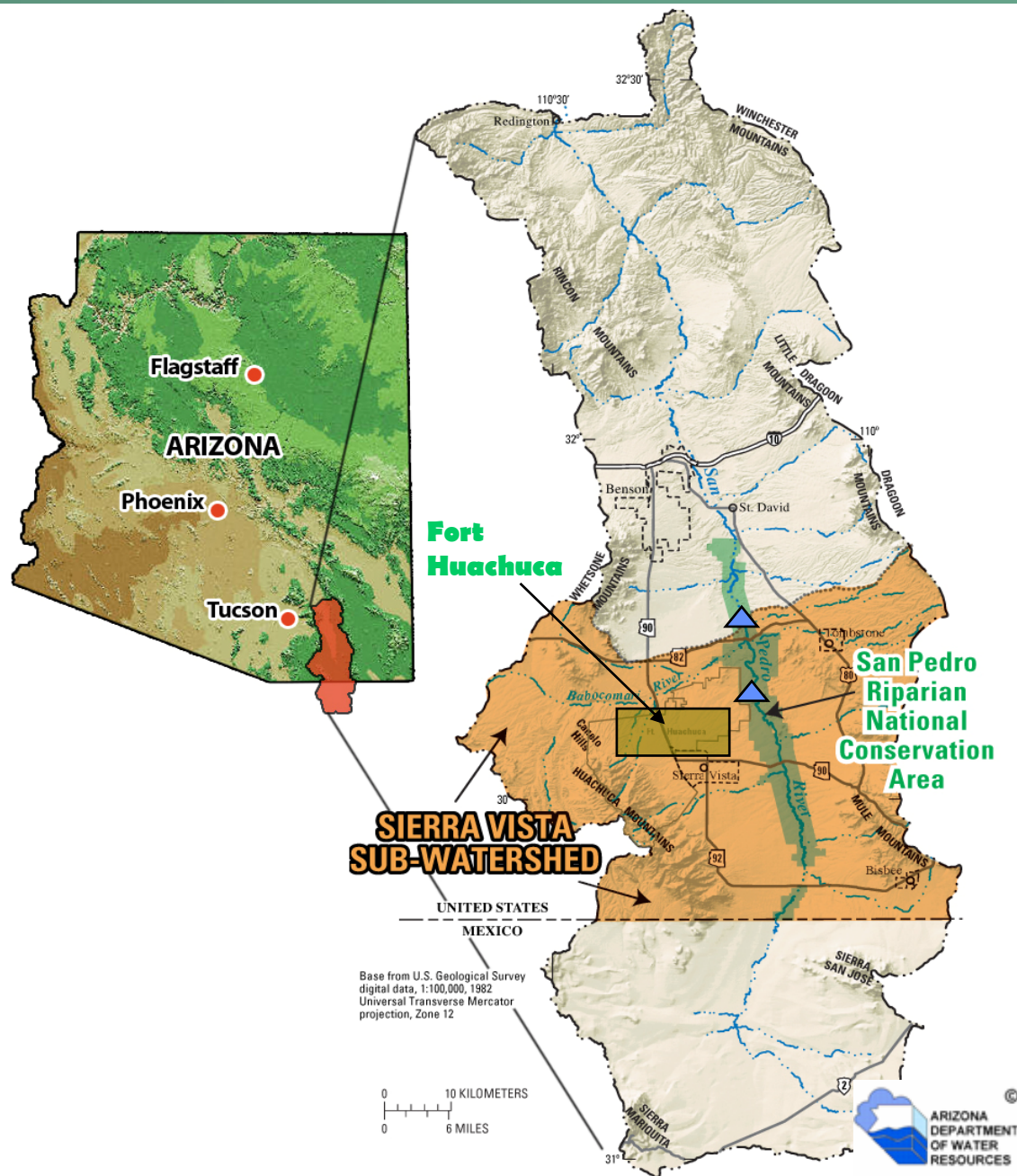
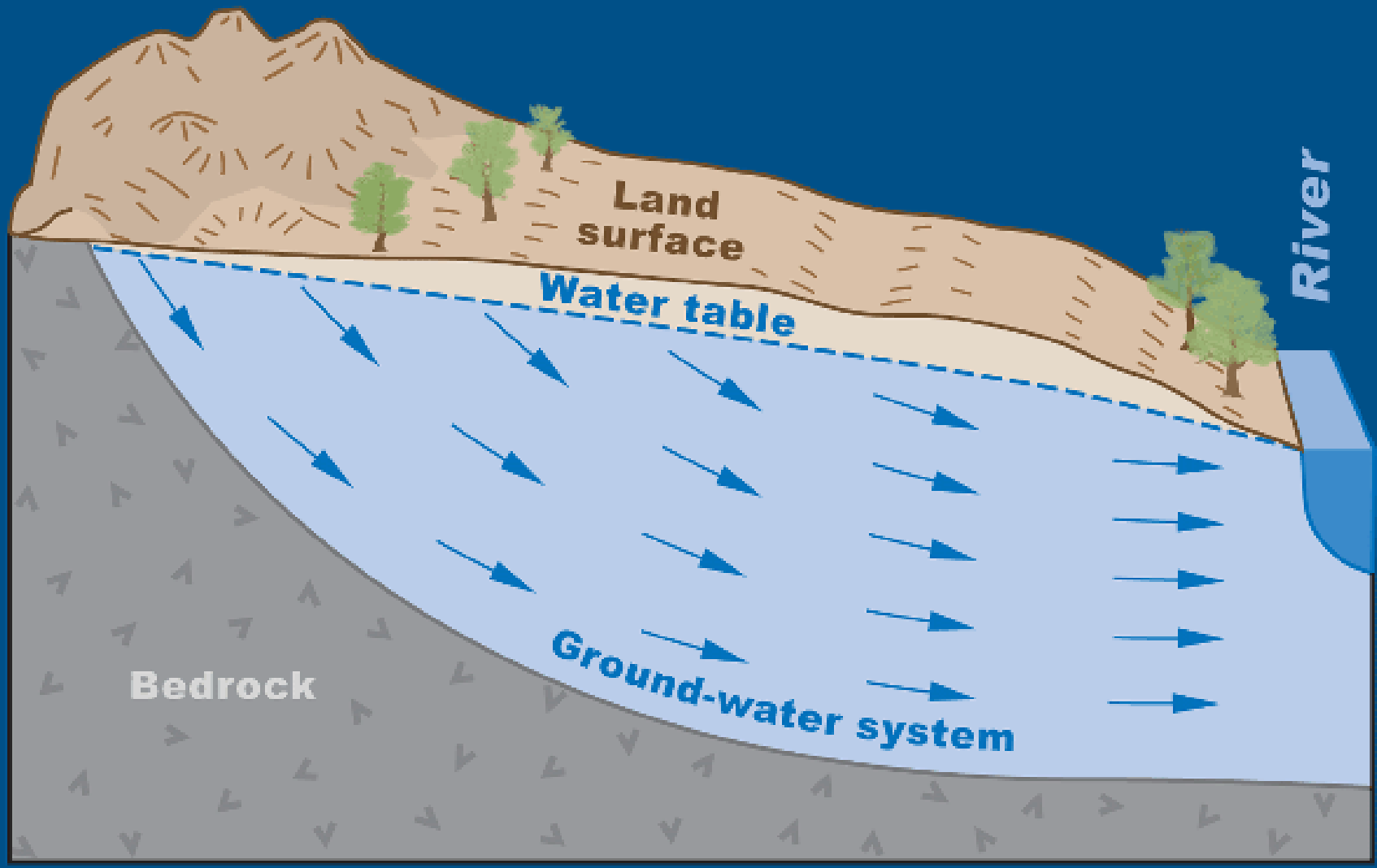
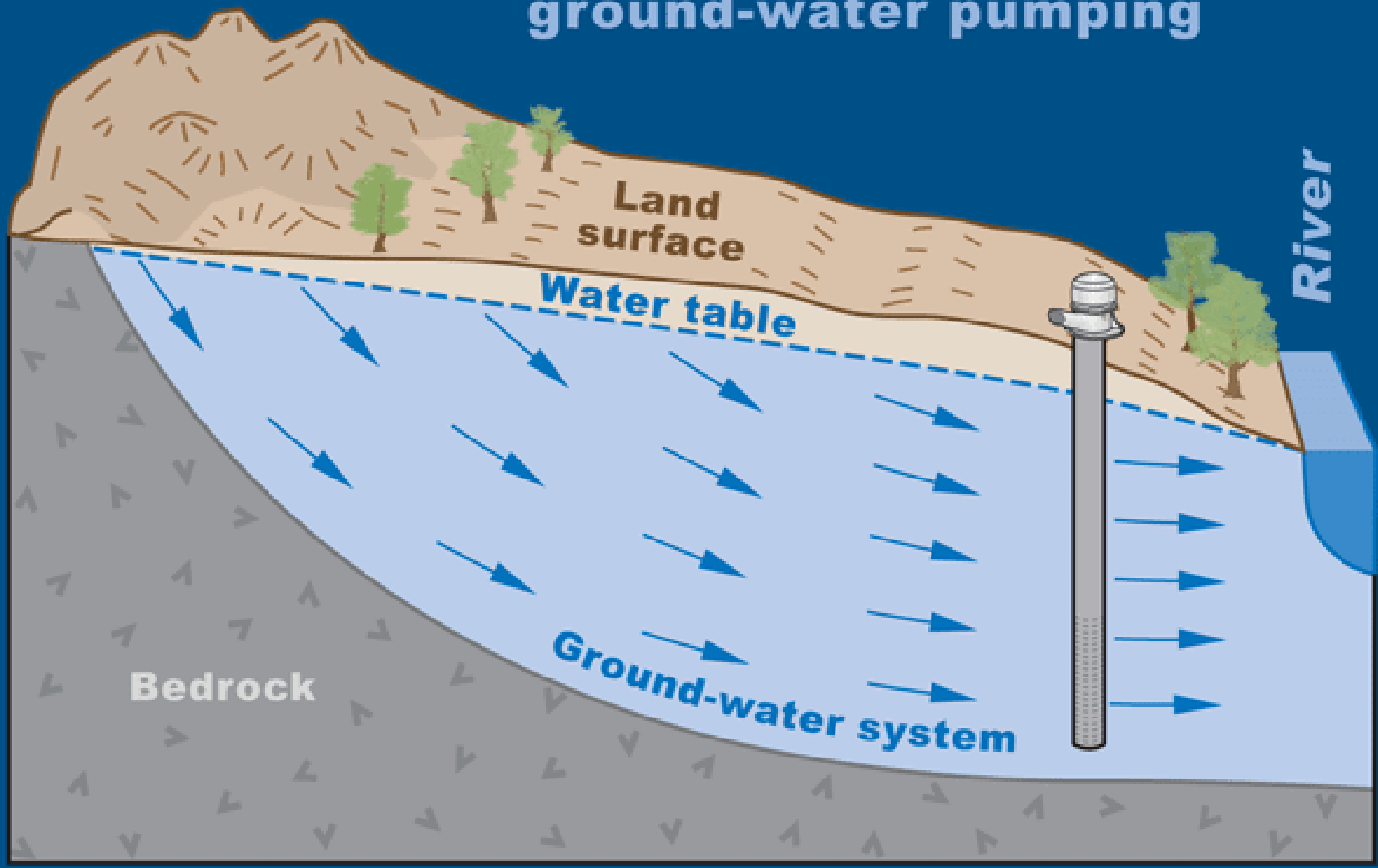


Natural conditions



Equilibrium change caused by ground-water pumping



Fundamental Hydrologic Issues

- Impacts of ground-water withdrawals on streamflow were difficult to quantify because…
  - Rates and distributions of recharge were poorly understood
  - Interactions between the aquifer and river were poorly defined
    - Where are they well connected ?
    - Where are they separated ? (clay layers)
  - Extents of flow-controlling layers were poorly defined
  - Relation between hydrology and riparian vegetation was not well known

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Objectives

- Provide information that will help answer the big question through investigation of….
  - Aquifer shape and locations of thick deposits of silt and clay
  - Locations where recharge occurs
  - Where base flow to the streams originate
  - The relation between hydrology and riparian ecology

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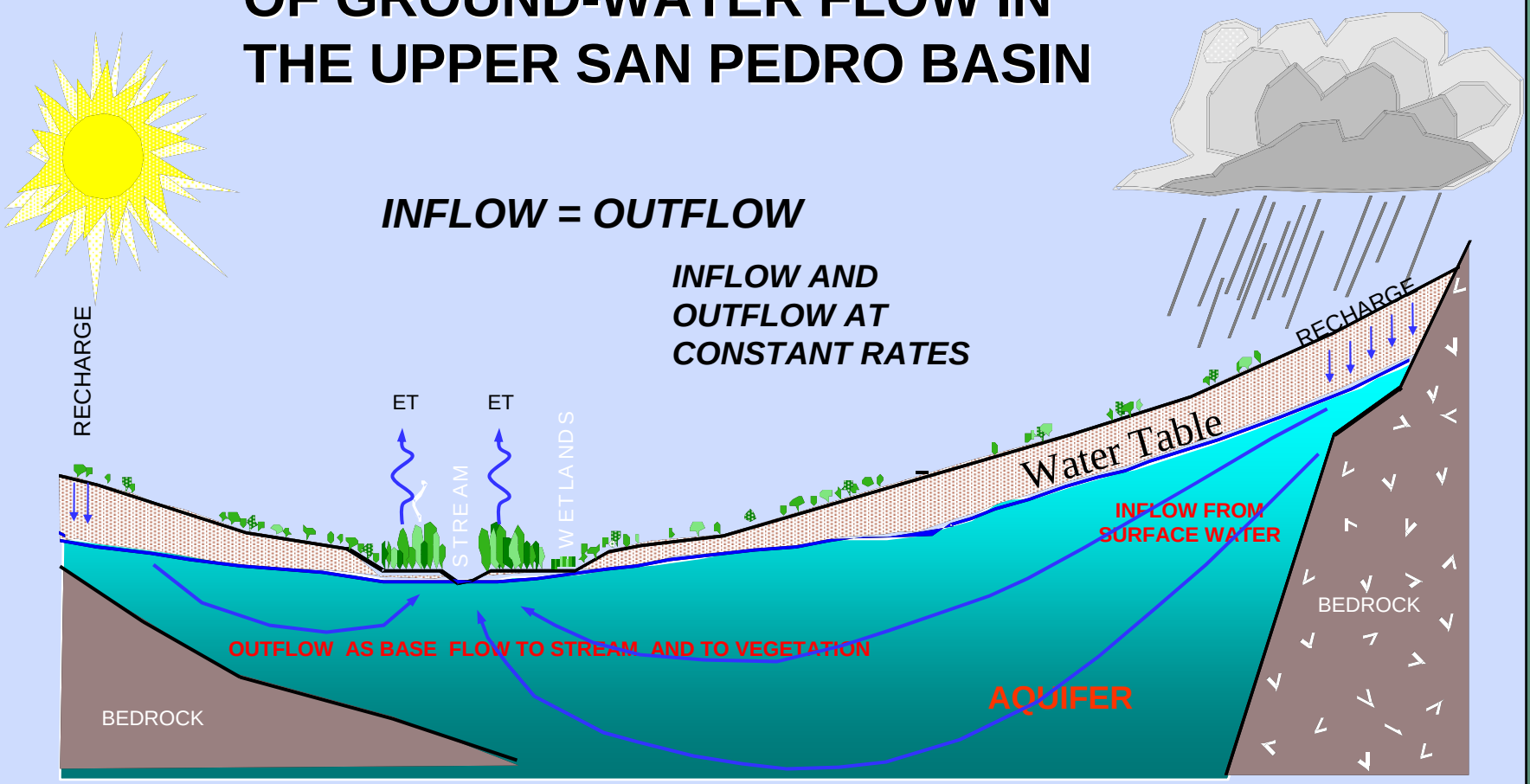
SIMPLE CONCEPTUAL MODEL OF GROUND-WATER FLOW IN THE UPPER SAN PEDRO BASIN



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Early USGS activities

- 1904 -Streamgage at Charleston established
  - Nearly continuous record
- 1930 –Streamgage at Palominas established
  - Intermittent data prior to 1950
  - Operated by IBWC 1981 thru 1994
- 1965 -Water Resources of Fort Huachuca
  - Water Supply Paper 1819-D1982: Ground-water flow model of Upper San Pedro basin (Sierra Vista Subwatershed)
- 1982 – Open File Report 82-752: Ground-water flow model of Upper San Pedro basin (Sierra Vista Subwatershed)

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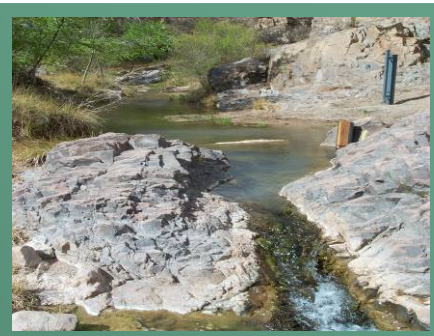
RWI/Upper San Pedro Partnership Geohydrologic Studies

- Water levels



- Streamflow
- Aquifer storage change - microgravity

- Geophysical exploration
- Ephemeral channel recharge
- Stream temperature monitoring

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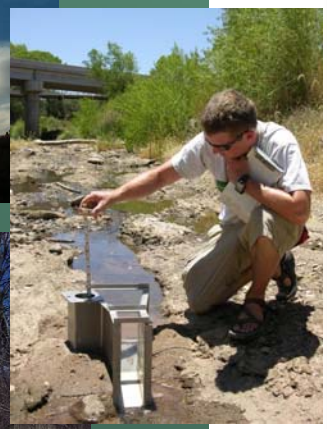
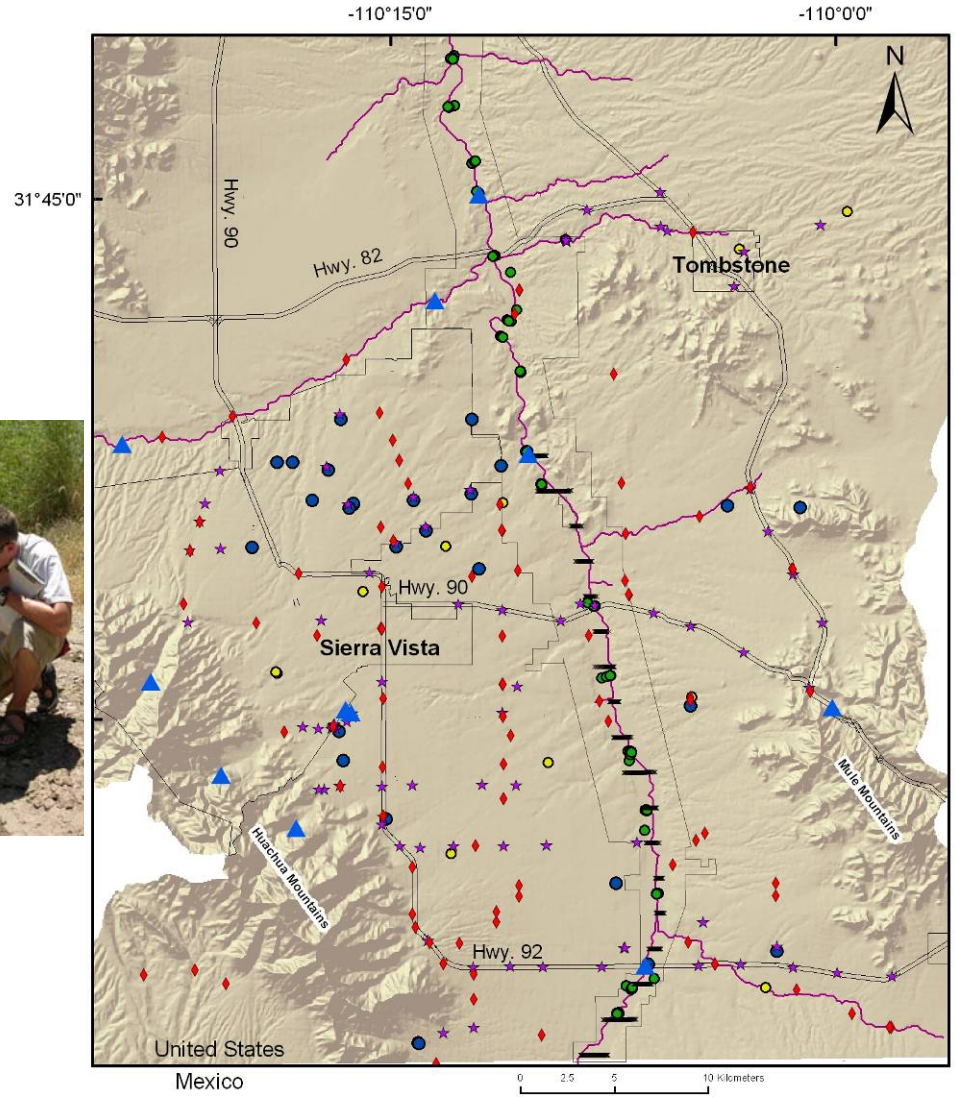
Investigations Network





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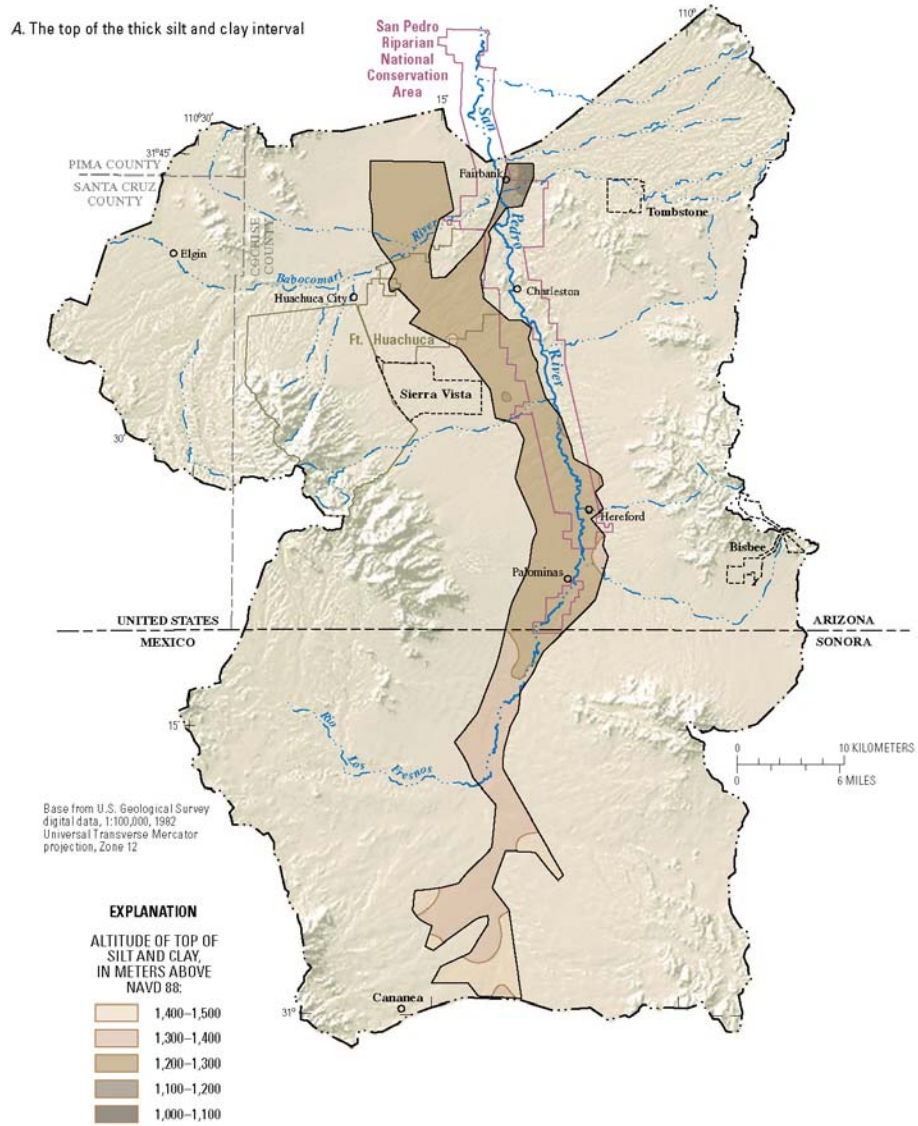
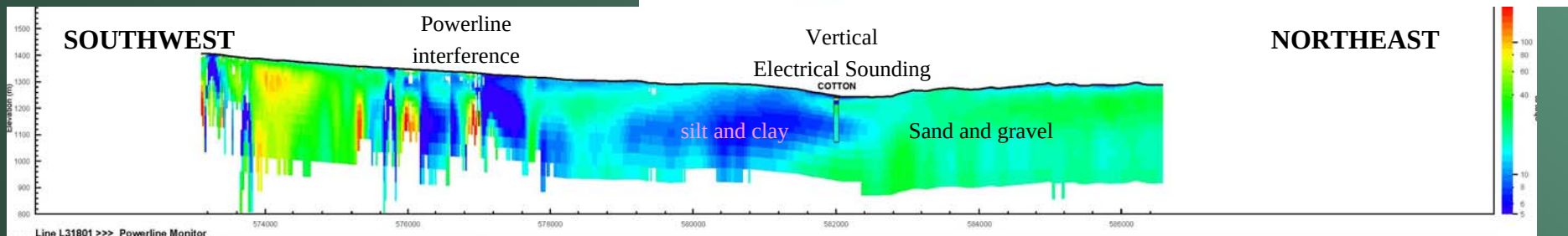
Geophysics

- **Result: delineation of regional silt and clay layer extent**





Ephemeral Channel Flow

- Temperature used to define flow presence and duration.

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Prepared in cooperation with the BUREAU OF LAND MANAGEMENT

Timing and Duration of Flow in Ephemeral Streams of the Sierra Vista Subwatershed of the Upper San Pedro Basin, Cochise County, Southeastern Arizona

Scientific Investigations Report 2005–5190

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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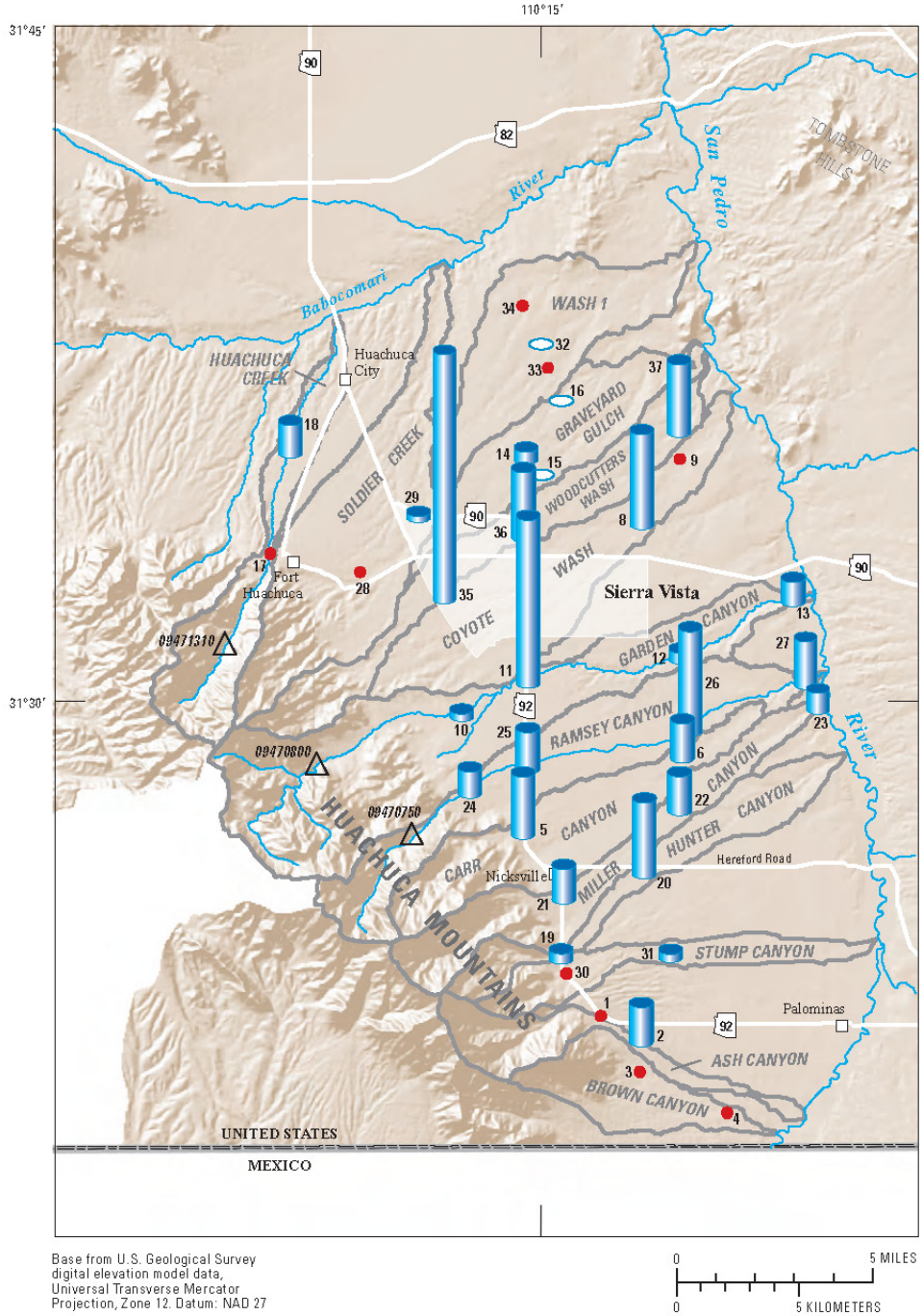
Ephemeral Channel Flow

- Very low durations in some locations
- Increased duration near urbanized areas



Ephemeral-channel recharge

- Boreholes
- Temperature
- Soils mapping
- Sediment texture
- Water levels
- Modeling

USGS

Prepared in cooperation with the
BUREAU OF LAND MANAGEMENT

Ephemeral-Stream Channel and Basin-Floor Infiltration and Recharge in the Sierra Vista Subwatershed of the Upper San Pedro Basin, Southeastern Arizona

Open-File Report 2005–1023

U.S. Department of the Interior
U.S. Geological Survey

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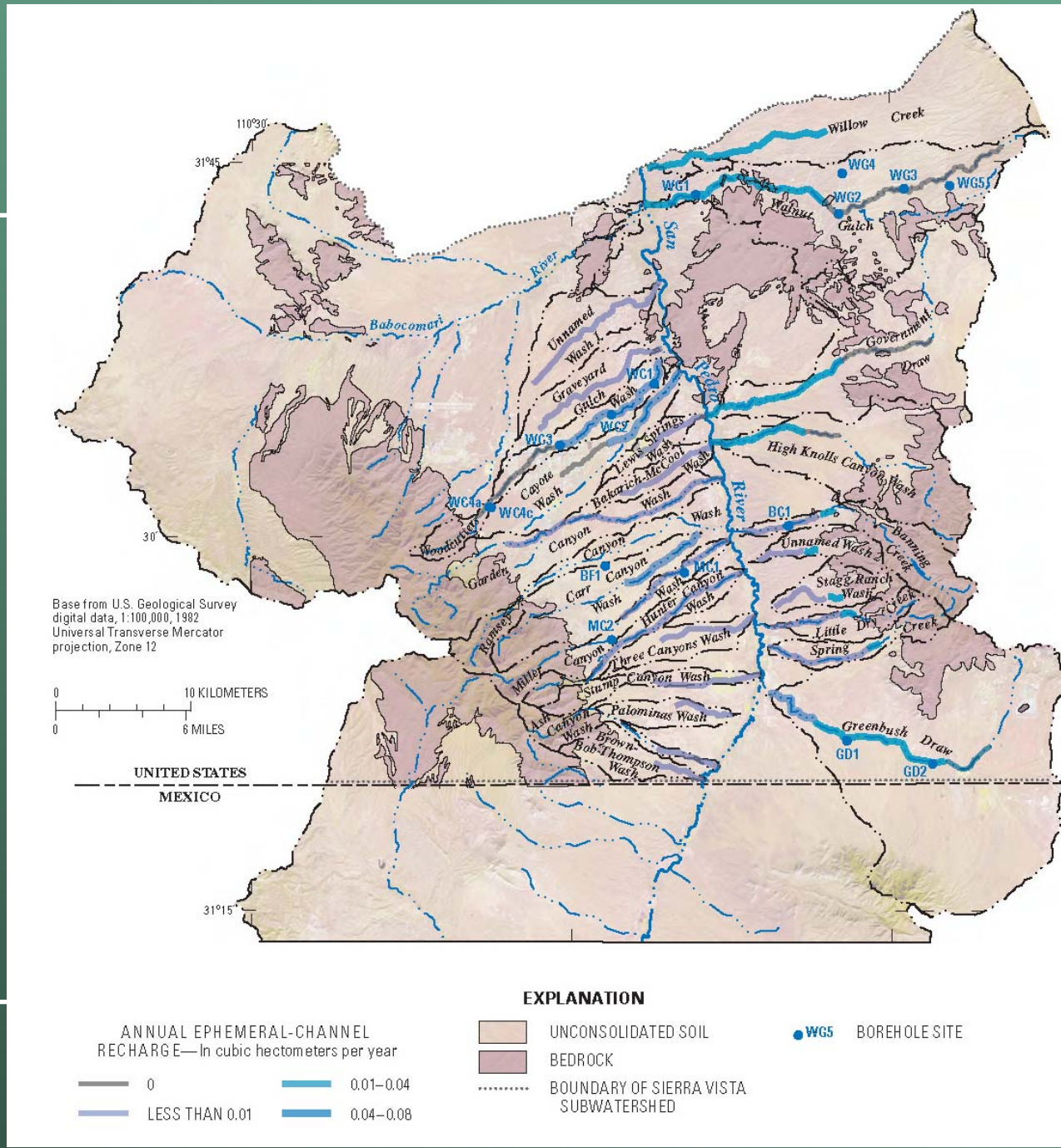
Ephemeral-channel recharge

- **Result: about 15 percent total basin recharge in ephemeral channels**



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Streamflow trends

- Examined trends regionally and at Charleston
- Streamflow
  - Annual flow
  - Peak flow
  - Low flow
- Precipitation

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Trends in Streamflow of the San Pedro River, Southeastern Arizona, and Regional Trends in Precipitation and Streamflow in Southeastern Arizona and Southwestern New Mexico

Professional Paper 1712

U.S. Department of the Interior
U.S. Geological Survey

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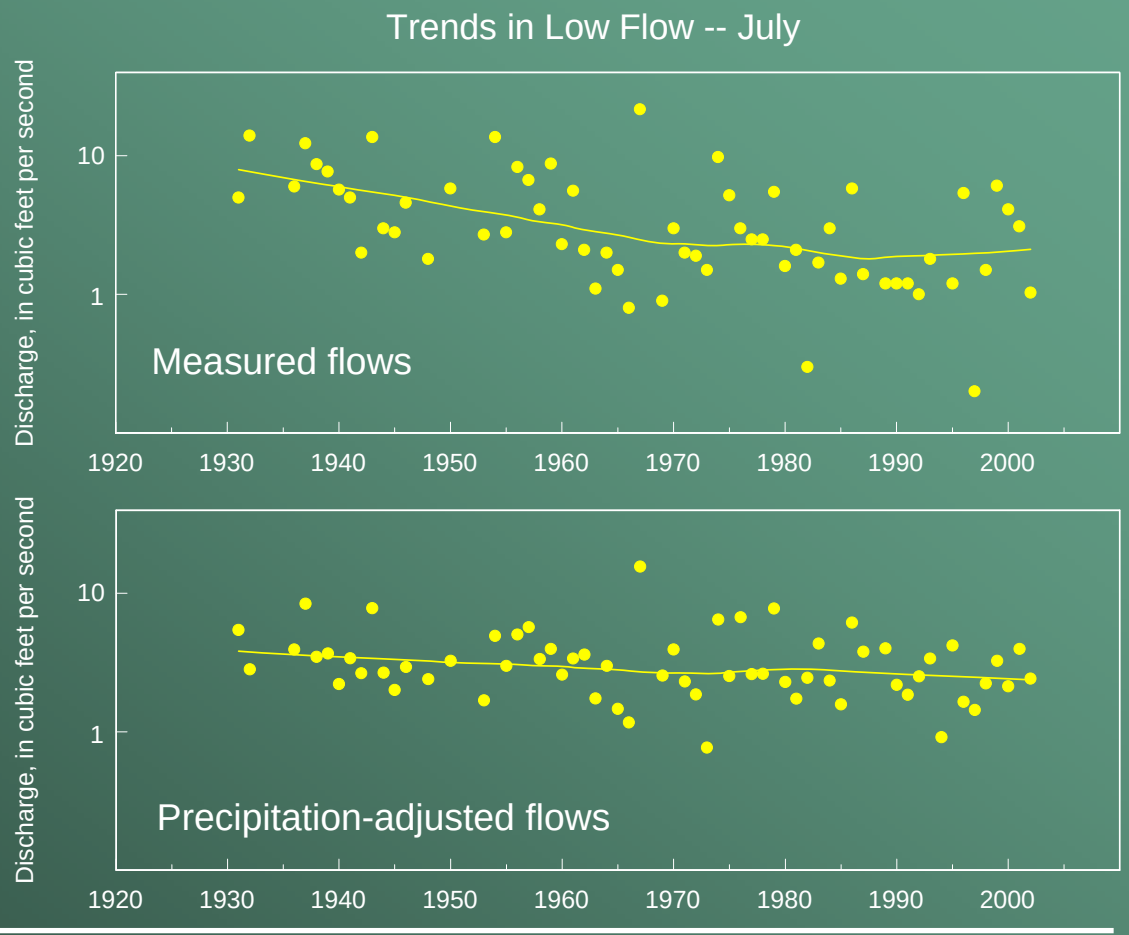
Streamflow trends

- Major factors
  - Precipitation
  - Near-stream pumping
  - Riparian vegetation
  - Upland vegetation



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Riparian Water Needs

- Hydrologic observations
- Riparian vegetation data
- Measurements of evapotranspiration

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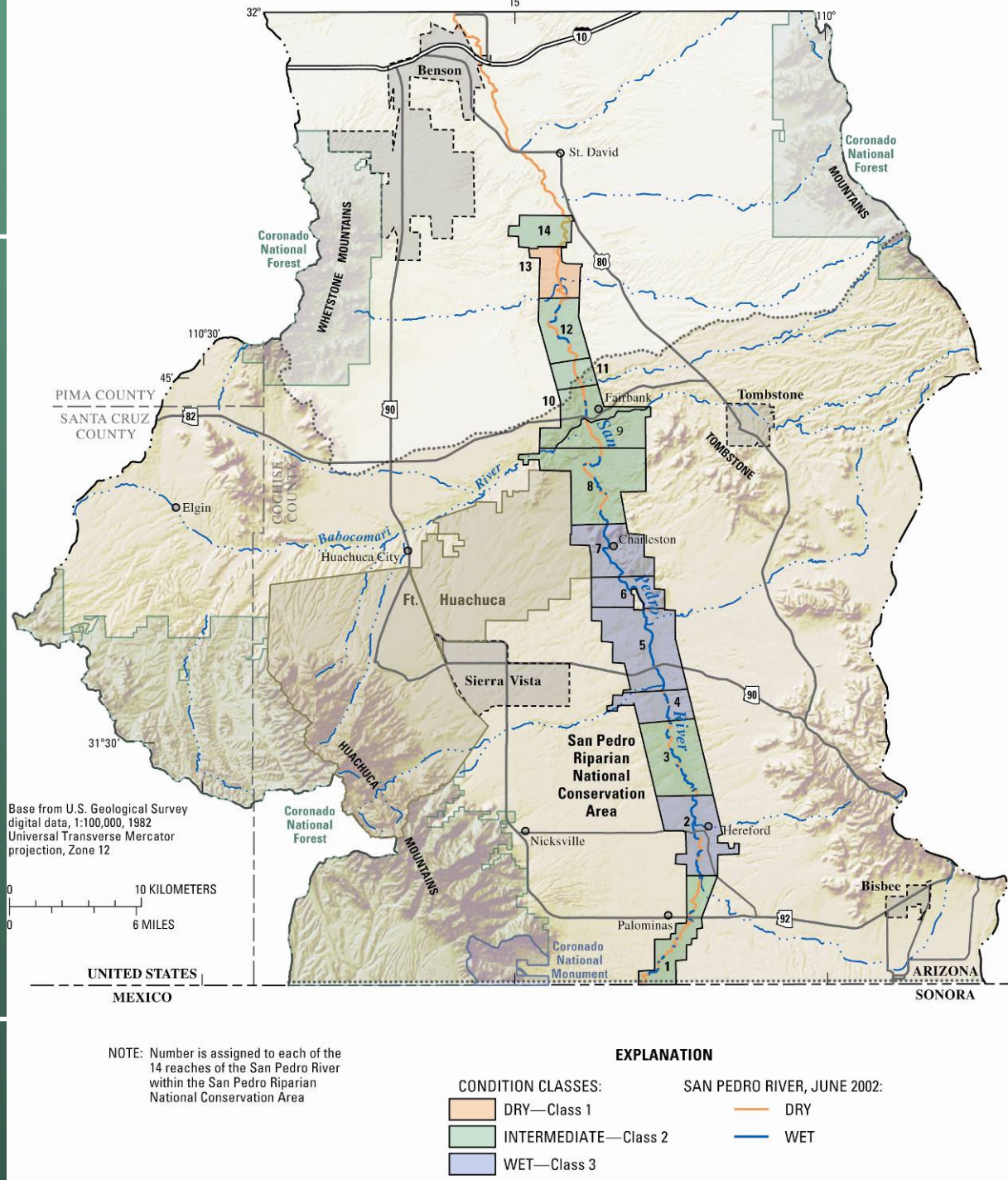
Riparian Water Needs

- Evapotranspiration estimate raised 40 percent
- Lowest ground-water variability in wettest reaches
- Five percent of stream in driest condition class



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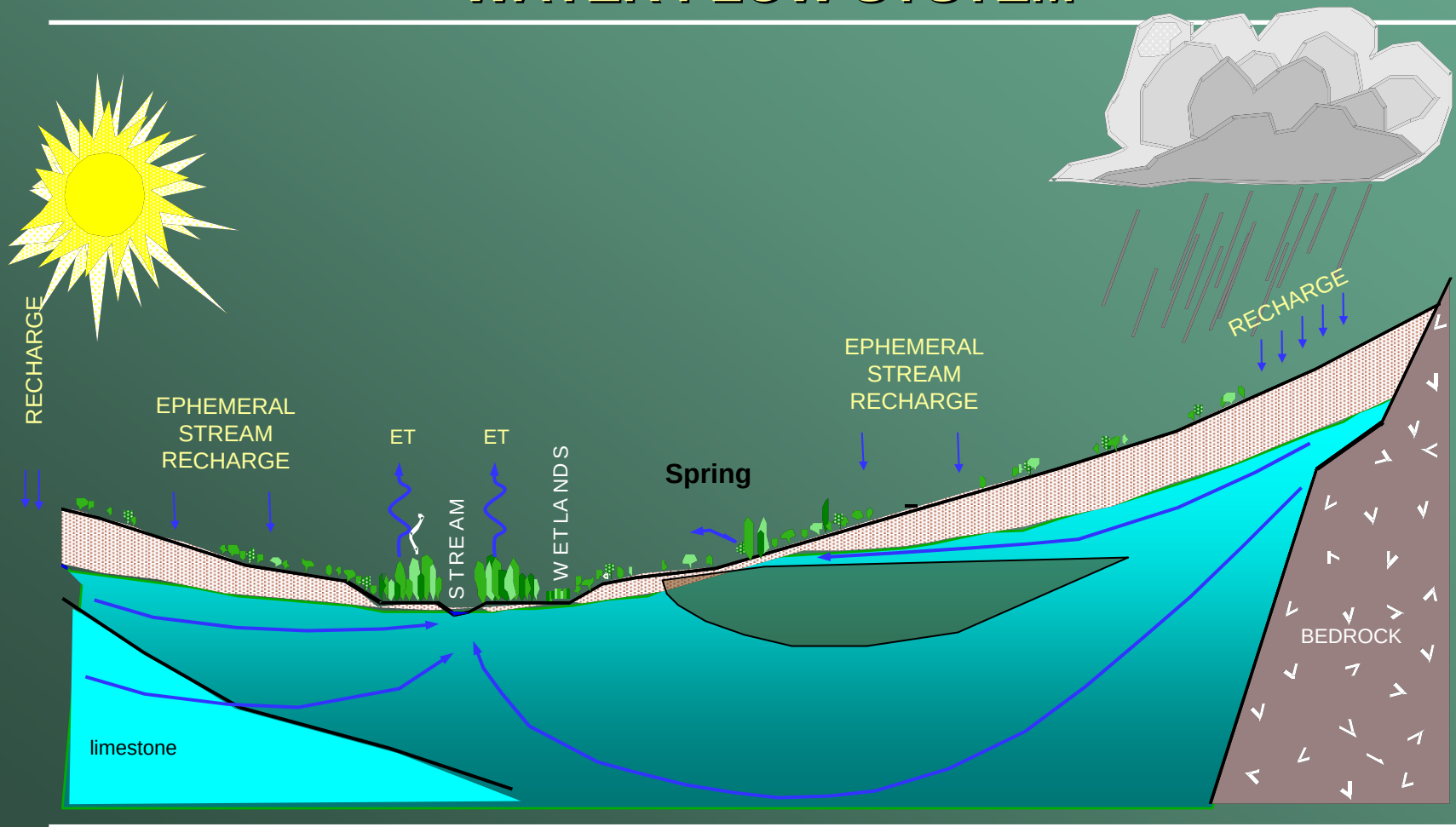
IMPROVED CONCEPTUAL GROUND-WATER FLOW SYSTEM

EAST

WEST



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Ground-Water Model

- A synthesis of what was learned in investigations
- Tool for understanding the hydrologic system
- Tool for understanding consequences of management actions

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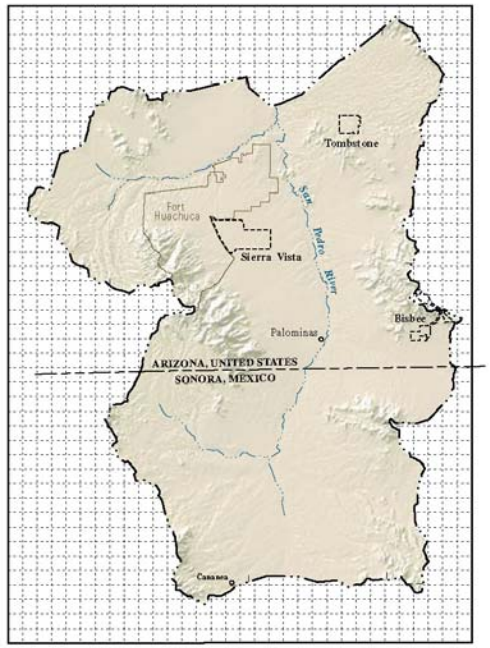
USGS science for a changing world

Prepared in cooperation with the
UPPER SAN PEDRO PARTNERSHIP and BUREAU OF LAND MANAGEMENT

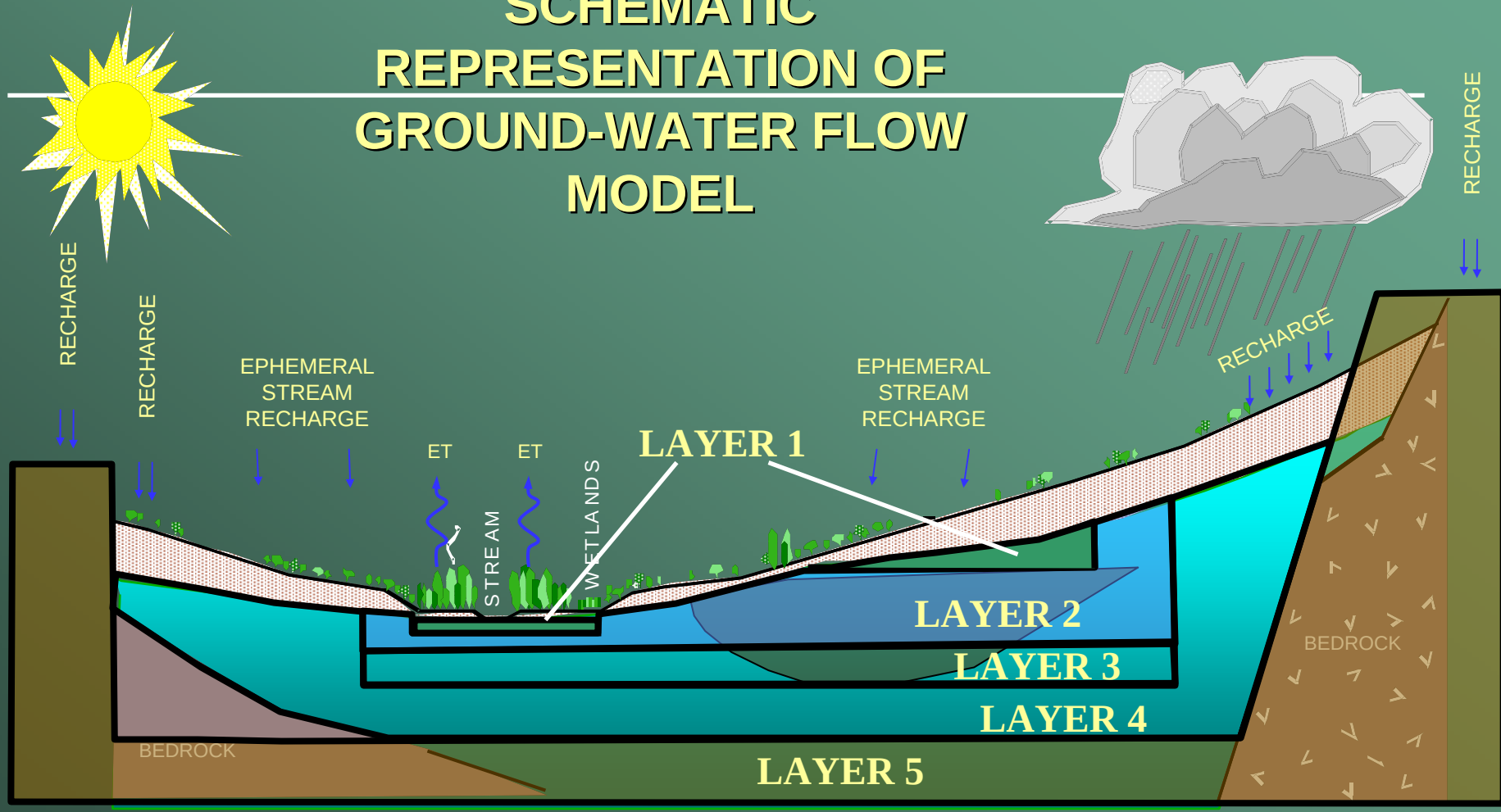
Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico



Scientific Investigations Report 2006–5228

U.S. Department of the Interior
U.S. Geological Survey

SCHEMATIC REPRESENTATION OF GROUND-WATER FLOW MODEL



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Science Informing Policy

- Tools to connect actions to consequences
- Spatial definition of ground-water management
- “Capture map”

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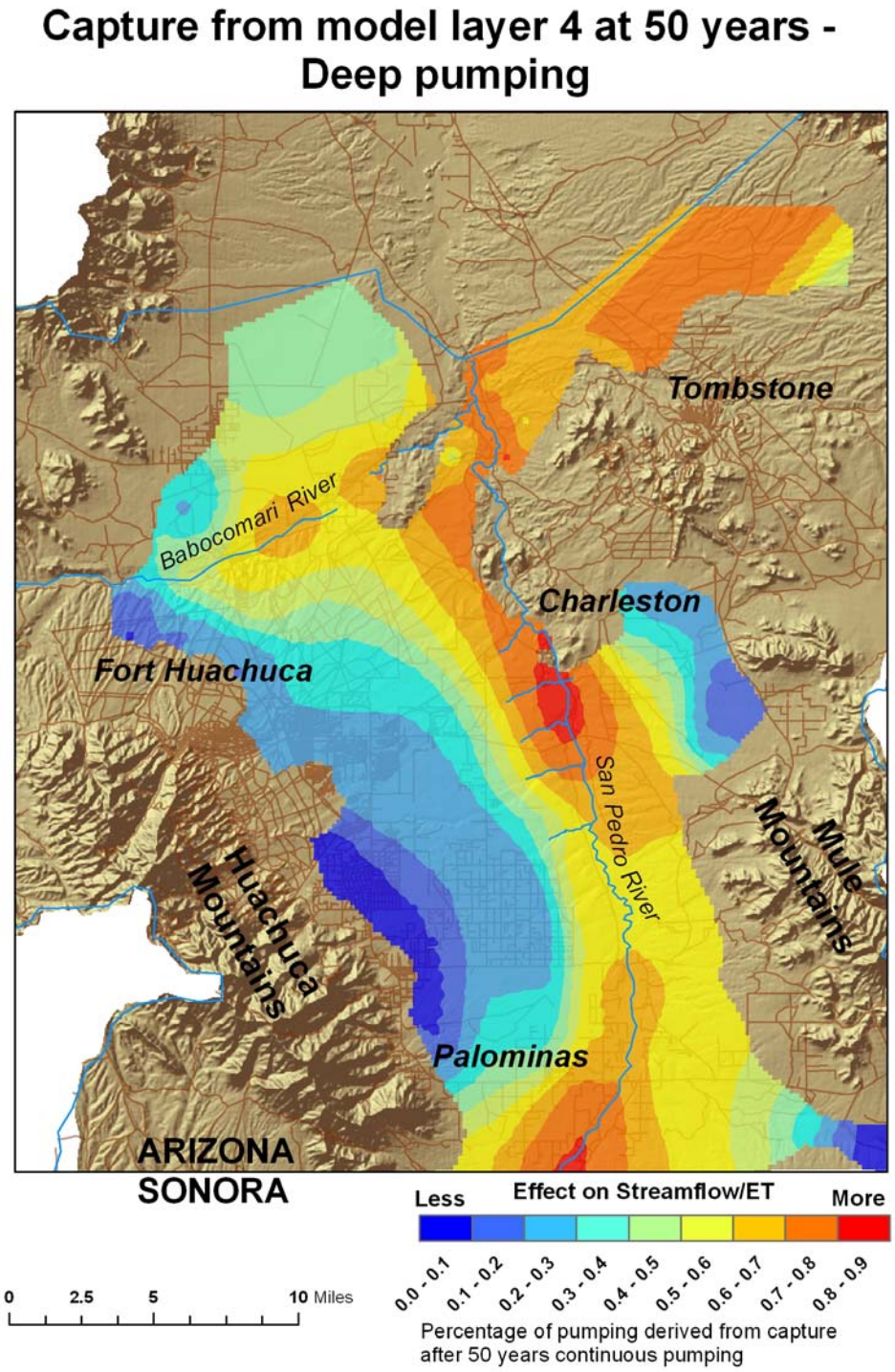

Sustainable Yield

- Stipulated by Congress in 2004
- Not safe yield --> pumping = recharge
- Sustainable Ground-Water Yield
  - "…the development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences."

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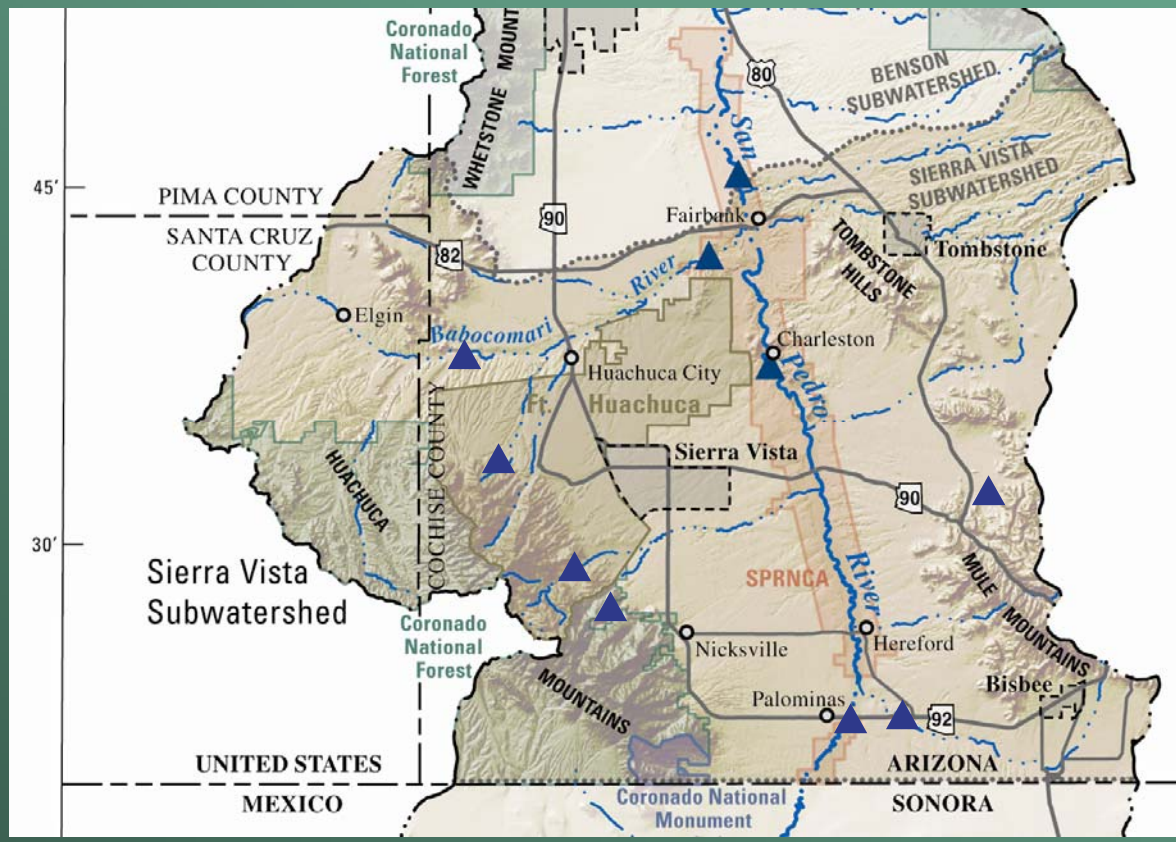
Need for Long Term Monitoring – Adaptive Management

- Iterative interaction
  - Management Action
  - Monitoring
  - Analysis



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USGS Semiarid: Only half of the residents drive camels

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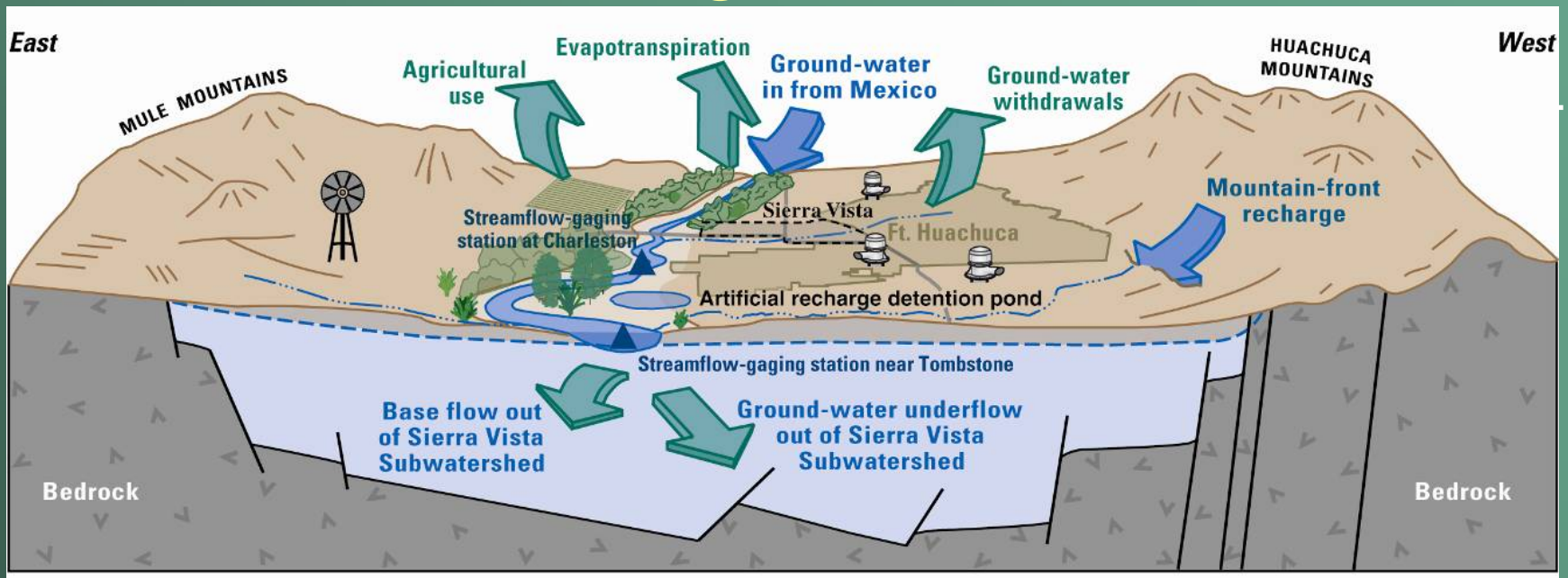
Ground-Water Budget



Simulated annual water budget for a ground-water-flow model — Values are in acre-feet per year

GROUND-WATER INFLOW

	Estimated range	2002 Estimates	2011 Projections
—Natural recharge	11,200–16,000	15,000	15,000
—Underflow from Mexico	3,000–3,400	3,000	3,000
—Total		18,000	18,000

GROUND-WATER OUTFLOW

	Estimated range	2002 Estimates	2011 Projections
—San Pedro base flow	3,250–6,290	3,250	3,250
—Net ground-water withdrawals		16,500	18,600
—Riparian and wetland evapotranspiration	6,230–7,700	7,700	7,700
—Ground-water underflow at Tombstone streamflow-gaging station	300–440	440	440
—Total		27,900	30,000

ANNUAL STORAGE CHANGE (no management measures)

—2002 Estimated	–9,900
—2011 Projected	–12,000

Water budget of the Subwatershed - 2005

Component	Estimated volume	Description
Natural aspects of system		
Natural recharge[1]	15,000	Inflow largely from percolating waters on and around mountains and through ephemeral channels
Ground-water inflow[1]	3,000	Subsurface inflow from Mexico
Ground-water outflow[1]	-440	Subsurface outflow at USGS San Pedro River near Tombstone streamflow-gaging station (09471550)
Stream base flow[1]	-3,250	Ground-water discharge to the river that flows out of the subwatershed
Evaporation and plant transpiration[1,8]	-7,700	Ground water consumed in the riparian system exclusive of evapotranspiration supplied by near-riparian recharge from precipitation or flood runoff
Pumping		
Pumping. water companies and public supply– gross	-10,830	Ground-water extractions by water companies and municipalities
Pumping, rural/exempt well – gross	-4,900	Ground-water extractions by private wells
Pumping, industrial (turf, sand, and gravel) – gross	-1,430	Ground-water extractions for industrial and golf course uses
Pumping, irrigation – net[2]	-1,480	Ground-water extractions for agricultural use
Active management measures		
Reduction of riparian evapotranspiration	475	Management of invasive mesquite
Municipal effluent recharge[3]	2,380	
Detention basin recharge[4]	130	
Passive recharge resulting from human activities		
Incidental recharge[5]	2,310	
Urban-enhanced recharge[6]	2,300	
Aquifer storage change[7]	-4,400	Additions or reductions in stored aquifer water

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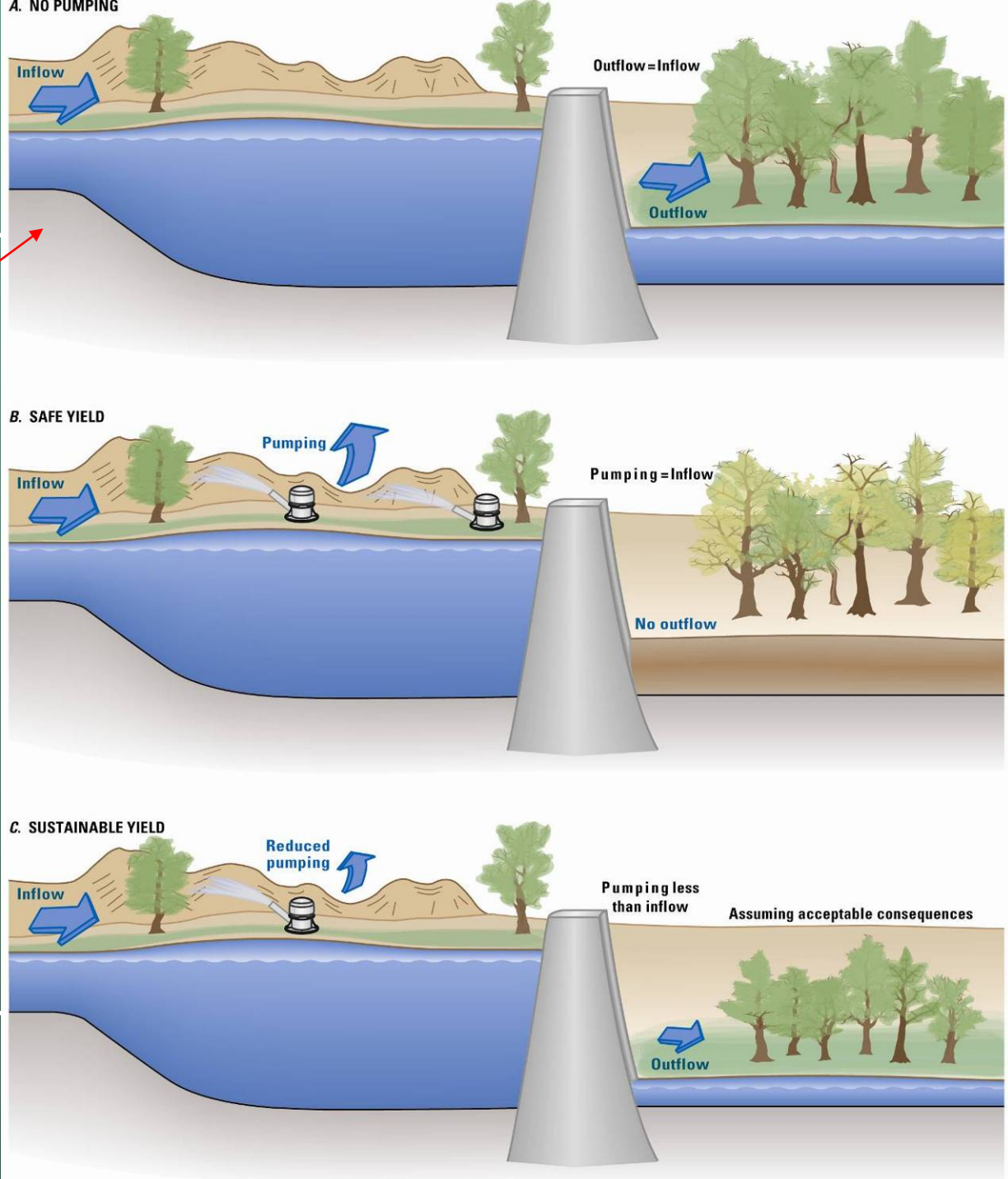
Reservoir Analogy

No Pumping

Safe Yield

Sustainable Yield



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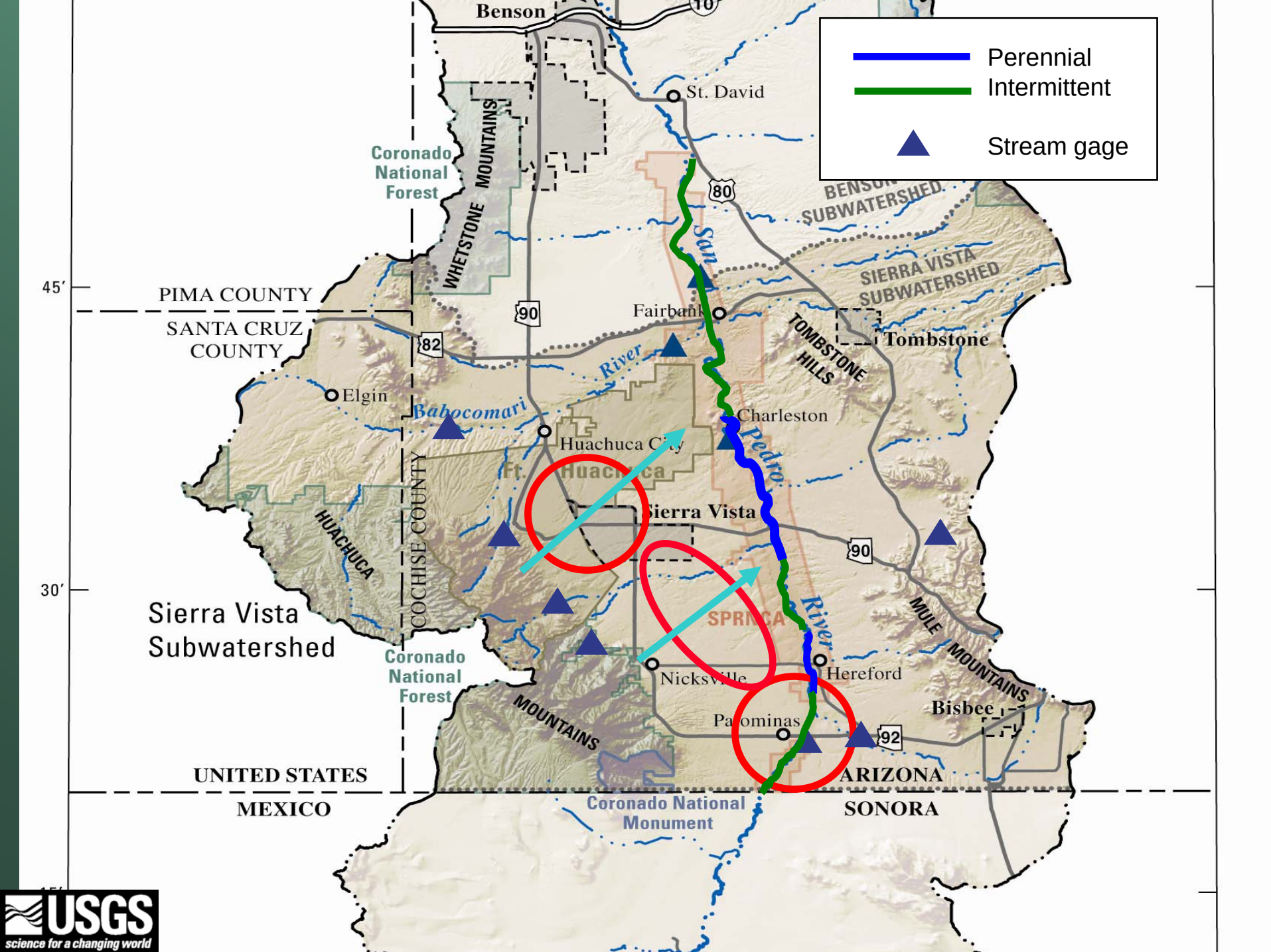
Perennial
Intermittent
Stream gage
Benson
St. David
Coronado National Forest
WHETSTONE MOUNTAINS
BENSON SUBWATERSHED
SIERRA VISTA SUBWATERSHED
San Pedro River
Fairbank
Tombstone
TOMBSTONE HILLS
PIMA COUNTY
SANTA CRUZ COUNTY
Elgin
Babocomari River
Huachuca City
Ft. Huachuca
Charleston
Sierra Vista
COCHISE COUNTY
HUACHUCA MOUNTAINS
Sierra Vista Subwatershed
SPRING CANYON
Nicksville
Hereford
MULE MOUNTAINS
Bisbee
Palominas
MOUNTAINS
UNITED STATES
MEXICO
ARIZONA
SONORA
Coronado National Monument
10
80
90
82
92
45′
30′

Outline

- Introduction to basin – talk about SPRNCA – usual superlatives, Fort, Cities
- The issues – declining streamflows, zero flow.
- Discussion of the players
- Capture
- History of needed information
- Description of work done –
  - Geophysical investigations
  - Stream-aquifer interactions
  - Streamflow trends
  - Ephemeral channel flow
  - Ephemeral channel recharge
  - Riparian water needs
  - Model.
- Sustainable yield goal – Section 321
- Status of water budget – include reservoir analogy to sustainable yield
- Science to policy section
  - Section 321 reports
  - Capture maps
  - Level change maps
  - Gravity maps

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